SEISMIC RESPONSE OF COMPOSITE BUILDING FRAME WITH ALTERNATE BRACING SYSTEM CONSIDERING SOIL STRUCTURE INTERACTION (SSI)

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Abstract

Conventional fixed-base analysis ignoring the effect of soil-flexibility carried out for the seismic design of buildings may result in unsafe design. Therefore, the effect of SSI is an important issue from the viewpoint of design considerations. Thus to evaluate the realistic behavior of structure the soil structure interaction (SSI) effect shall be incorporated in the analysis. In seismic analysis provision of bracing system is one of the important option for the structure to have sufficient strength with adequate stiffness to resist lateral forces. The different configuration of these bracing systems alters the response of buildings, and therefore, it is important to evaluate the most effective type and location of the bracing systems in view point of stability against SSI effect. In present study, two RC building frames, G+10 and G+15 with six different combinations of steel bracing system at alternate locations incorporating the effect of soil flexibility is considered in order to investigate the effectiveness of bracing system to control SSI. The seismic analysis is carried out using equivalent static method as per IS 1893-2002 The study is carried out using Elastic continuum approach(ECM) The influence of SSI on various seismic parameters and the flexural parameters are presented. The changes in all these parameters due to provision of steel bracing system are studied in order to evaluate its effectiveness in controlling the SSI effect. The study reveals that, steel bracing system plays important role to control SSI effect and it is observed that diagonal bracing placed at mid periphery are more effective, in resisting seismic load considering SSI.

Keywords: *Steel Bracing System, Soil Structure Interaction, Elastic Continuum Approach, Natural Period.*

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1. INTRODUCTION

Most of the structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these structures, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI).

In conventional structural design it is assumed that building has a fixed base condition. However in reality it rests on flexible media (soil) which incorporates flexibility to the base resulting in to SSI phenomena. Neglecting effect of SSI in case of light structures resting on stiff soil is not significant. However, it becomes prominent for stiff structures resting on relatively soft soils

In case of Tall buildings, the gravity load resisting system cannot resist lateral forces efficiently. It is well recognized that the incorporation of lateral force resisting systems in the form of shear walls, bracing systems etc. improve the structural performance of building subjected to lateral forces due to earthquake excitation.

Bracing systems are used to resist horizontal forces (wind load, seismic action) and to transmit to the foundation. The bracing members are arranged in many forms, which carry solely tension, or alternatively tension and compression. Bracings hold the structure stable by transferring the loads sideways (not gravity, but wind or earthquake loads) down to the ground and are used to resist lateral loads, thereby preventing sway of the structure There are different types of bracing systems in common use such as single diagonal bracing, X bracing, V bracing, K bracing, inverted V bracing.

Further, the position of bracings in a building alters the response of structure. It is desirable to decide the position of the bracings, so that maximum benefit can be derived. Similarly, incorporation of SSI in the analysis is desirable to estimate the most realistic performance of the structure. In view of the above in the present study an attempt is made to investigate effect of SSI and also the effectiveness of alternate bracing system in the performance of the structure.

2. OBJECTIVE OF THE STUDY

1)To study the dynamic properties of building frame considering Soil Structure Interaction (SSI) effect.
2)To evaluate the effectiveness of alternate bracing system to reduce the SSI effect.
3)To identify the best possible type and location of bracing to control SSI and improve the overall performance of structure.

3. STUDY METHODOLOGY

3.1 Soil Idealization

Present study is done to focus on mainly SSI effect on various parameters of building frame. In the past many researchers have developed different approaches such as

Winklerian approach, Elastic continuum approach to investigate SSI effect. Elastic continuum approach (ECM) is considered in present study as it is possible to incorporate much complex condition in the analysis with high degree of realism.

ECM is a physical representation of the infinite soil media. In this method whole soil mass below the foundation which is under the influence of loading is considered. The soil mass, foundation and structure are discritized in small elements. The governing equations of motion for the structure incorporating foundation interaction and the method of solving these equations are relatively complex. Therefore, direct method is employed in this study and finite element software, SAP2000, is use to model the soil-structure system and to solve the equations for the complex geometries and boundary conditions. According to Rayhani and Naggar (2008), horizontal distance between soil boundaries is assumed to be five times the width of structure and bed rock depth is assumed to be 30 m. The whole soil mass, foundation and structure is idealized using finite element method (FEM).

3.1.1 Discritization of Structure for FEM Analysis

1) Beam and Column

Beam and column is modeled as a frame element**.** The element is defined by two nodes, the cross-sectional area, and the material properties. It is a uniaxial element with tension, compression and bending capabilities. The element has six degrees of freedom at each node, translations in the nodal x, y, and z directions and rotation about the nodal x, y, and z-axis.

2) Slab

Slab is modeled as plate element. A plate is a planer structure with a very small thickness in comparison to the planer dimensions. It has four corner nodes with three degrees of freedom (u_z, θ_x, θ_y) at each node.

3) Footing and Soil Mass

Footing and soil mass is modeled as solid element. The foundation discretized as eight-noded brick element with 3 DOF at each node with translations in the nodal x, y, and z directions. The soil mass beneath the footing is also discretized as eight-noded brick element. The soil mass is assumed to be linear, elastic and isotropic material. The typical elastic continuum model is shown in figure 1.

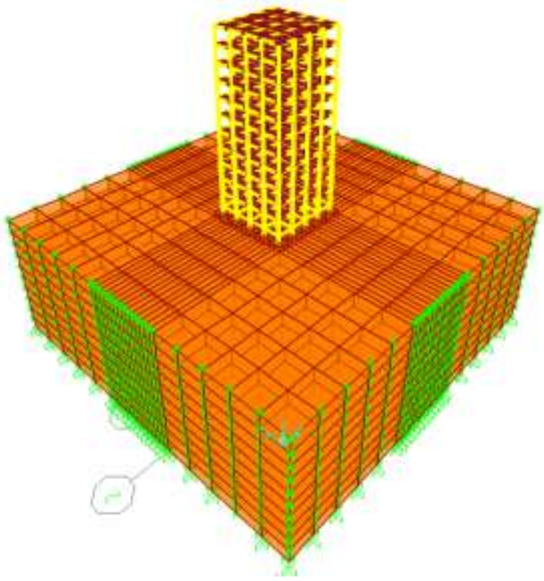


Fig -1: Typical view of Elastic Continuum Model

3.2 Structural Idealization

In this study two building frmes, G+10 and G+15 representing mid-rise ordinary moment resisting frame resting on medium soil is considered. The parameters of soil considered for this study are given in Table no 1. The structural sections of frame are designed as per IS-456; 2000.The details of building frame are given in Table no 2. The storey height is kept uniform of 3.5m. Different types of bracing arrangement such as diagonal, X and V at different location such as mid and corner have been considered for the analysis. Steel bracings are used in the present study and are designed as per IS-800; 2007.

The building with different bracing position and orientation is shown in Figure no 2. The sizes of beams, columns, bracings and slabs are kept same in all cases. The various parameters for all cases are evaluated by using SAP-2000 software.

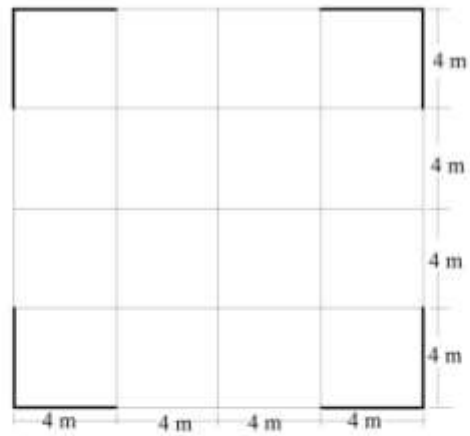
Table -1: Properties of soil

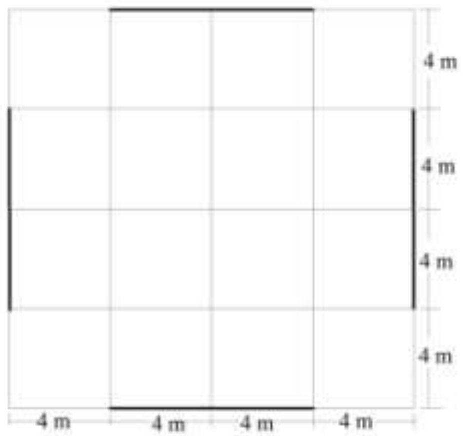
Sr. No.	Properties	Values
1	Modulus of Elasticity	50,000 kN/m²
2	Poisson's ratio	0.3
3	Unit weight	16 kN/m³
4	S.B.C	350 kN/m²

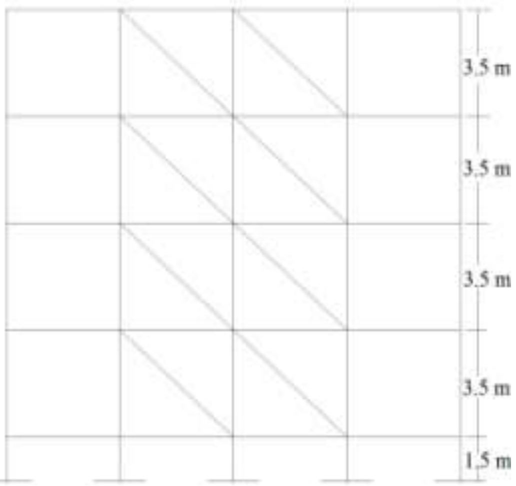
Table -2: Geometric and material properties of building frame.

Sr. No	Contents	Description	
1	No. of Stories	G+10	G+15
2	Type of Frame	OMRF	OMRF
3	Storey Height	3.5 m	3.5 m
4	Grade of Concrete	M 25	M 25
5	Grade of Steel	Fe415	Fe415
6	Bay width	4 m.	4 m.
7	Slab thickness	0.15 m	0.15 m

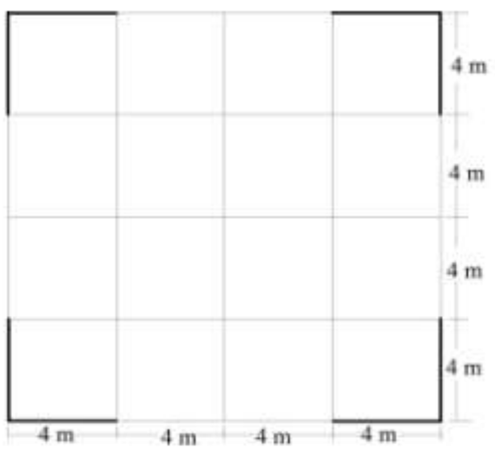
8	Size of Column	0.4m X 0.23 m (8th floor to roof)	0.25 m X 0.45 m (13th floor to roof)
		0.45m X 0.5 m (from 4th to 7th floor)	0.45 m X 0.50 m (from 9th to 12th floor)
		0.7m X 0.5 m (from base to 4th floor)	0.50 m X 0.70 m (from 5th to 8th floor)
			0.50 m X 0.95 m (from base to 4th floor)
9	Size of Beam	0.4mX 0.23m	0.4mX 0.23m
10	Size of Bracing	Diagonal-ISA 130x130x15	Diagonal-ISA 130x130x15
		X -ISA80x80x10	X -ISA80x80x10
		V -ISA110x110x12	V -ISA110x110x15
11	Floor finish	0.6 kN/m²	0.6 kN/m²
12	Live load	4 kN/m²	4 kN/m²

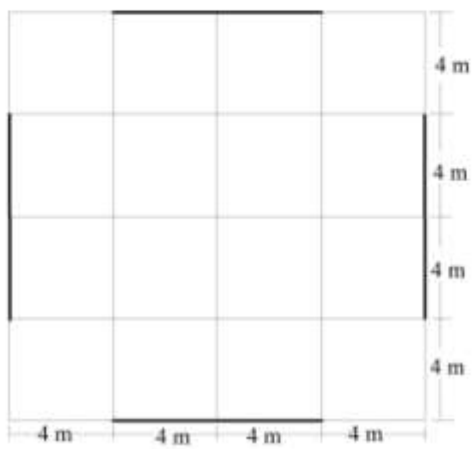


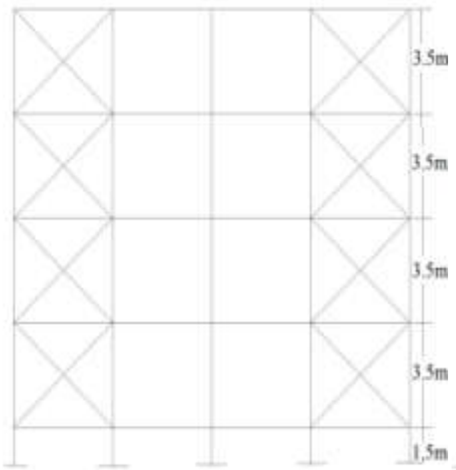




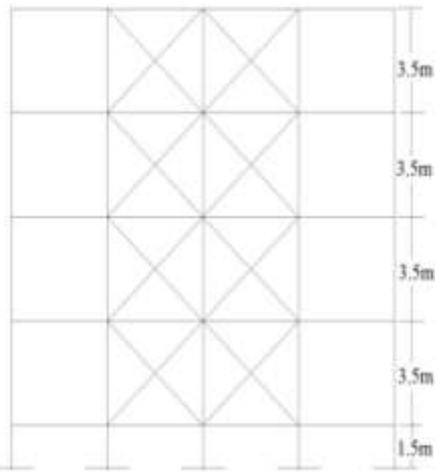
a) Diagonal corner bracing (DCB) b) Diagonal mid bracing (DMB)



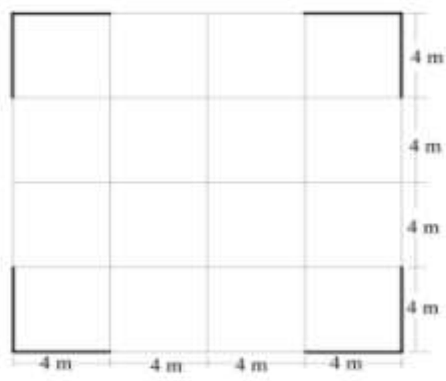


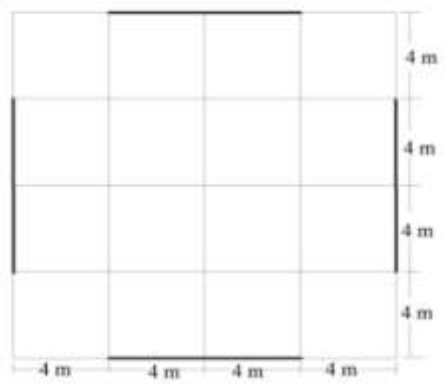


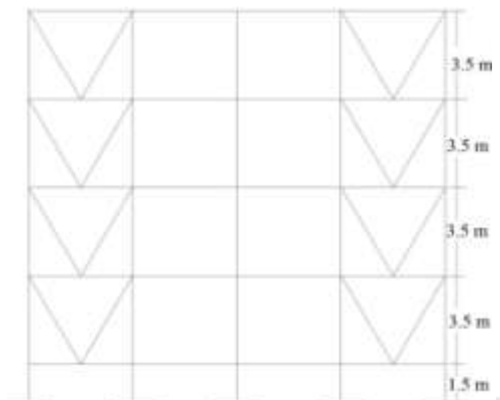
c) X corner bracing(XCB)



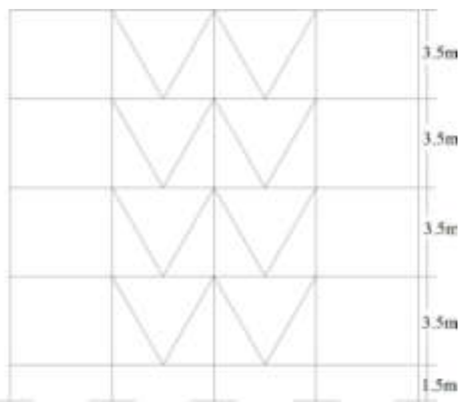
d) X mid bracing(XMB)







e)V corner bracing (VCB)



f) V mid Bracing (VMB)

Fig -2: Various Location of Bracing In Building Frame

4. PARAMETRIC STUDY

Various parameters are studied to investigate the effect of SSI and to identify the effectiveness of bracing system. The study is carried out on fixed base and flexible base condition. For flexible base condition various combinations of bracing systems are studied. The combinations of bracing system are given in Table no 3 below. These are discussed below.

Table -3: Different combinations of bracing system

Case	Designation	Notation
1	Fixed Base	FB
2	Flexible base with bare Frame.	(FL)BF
3	Flexible base with diagonal corner bracing	(FL)DCB
4	Flexible base with diagonal mid bracing	(FL)DMB
5	Flexible base with X corner bracing	(FL)XCB
6	Flexible base with X mid bracing	(FL)XMB
7	Flexible base with V corner bracing	(FL)VCB
8	Flexible base with V mid bracing	(FL)VMB

4.1 Natural Time Period.

The variation in Natural Time Period of structure for fixed base and flexible base conditions are presented in Figure 3 for G+10 and G+15 building frames respectively.

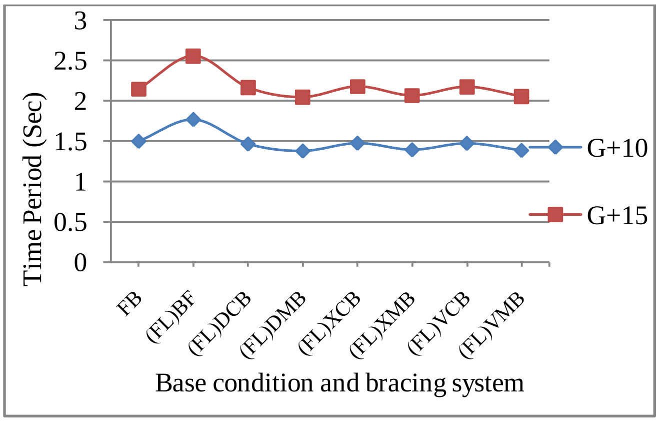


Fig -3: Variation of natural time period.

From Figure no 3 it is observed that as the support changes from fix to flexible base condition the Natural Time Period increases by 18% for G+10 building. However due to incorporation of bracing system it decreases in the range 16% to 22% .Among all the combinations of bracing system FDMB that is flexible diagonal mid bracing has least time period, signifying its effectiveness to control the SSI effect. The same trend is observed for G+15 building.

4.2 Column Bending Moment

The effect of SSI and bracing system on column bending moment on building frames is studied and the results are shown in Figure 4.

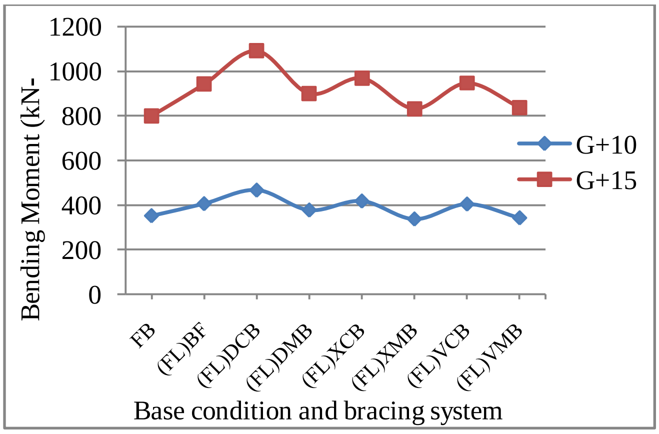


Fig -4: Variation of column bending moment.

From Figure no 4 it is observed that as the support changes from fix to flexible base condition column bending moment increases by 15% for G+10 building due to SSI effect. Due to incorporation of bracing system it reduces in the range of 3% to 17%. Among all the case X bracing at mid location (FXMB) shows least bending moment. For all the type of bracing corner location shows higher bending moment. However at mid location it reduces significantly. The same trend is observed for G+15 building.

4.3 Beam Bending Moment

The variations for Beam bending Moment are presented in Figure 5.

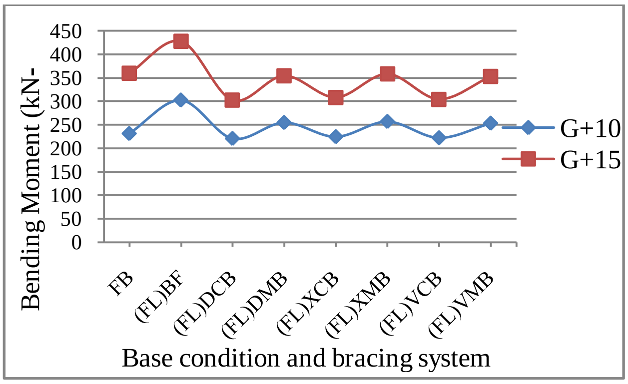


Fig -5: Variation of beam bending moment.

From Figure no 5 it is observed that as support flexibility changes from fix to flexible base condition beam moment increases rapidly. It increases by around 30% for G+10 building. However after the incorporation of bracing system it reduces significantly in the range of 15% to 30%.Among all the case diagonal corner bracing system (FDCB) is observed to be effective to control the SSI effect. Same trend is observed for G+15 building.

4.4 Storey Displacement

The variations for storey displacement for G+10 and G+15 building frame are presented in Figure 6 and 7 respectively.

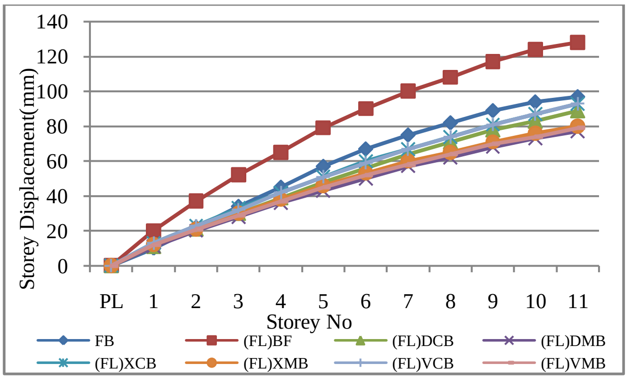


Fig -6: Variation of storey displacement (G+10).

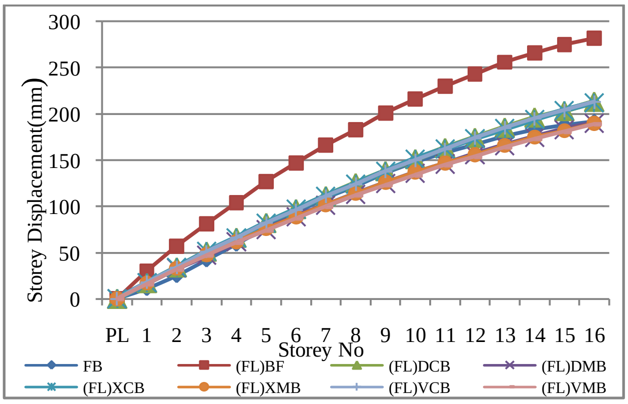


Fig -7: Variation of storey displacement (G+15).

From Figure 6 it is observed that as the support flexibility changes from fix base to flexible base condition storey displacement increases in the range of 31% to 68% for G+10 building. After the incorporation of various bracing system it reduces up to 45%. Among all position and orientation of bracings, the buildings with diagonal mid bracing that is FDMB has the least storey displacement. The same trend is observed for G+15 building.

4.5 Storey Drift

The variations for storey displacement for G+10 and G+15 building frame are presented in Figure 8 and 9 respectively.

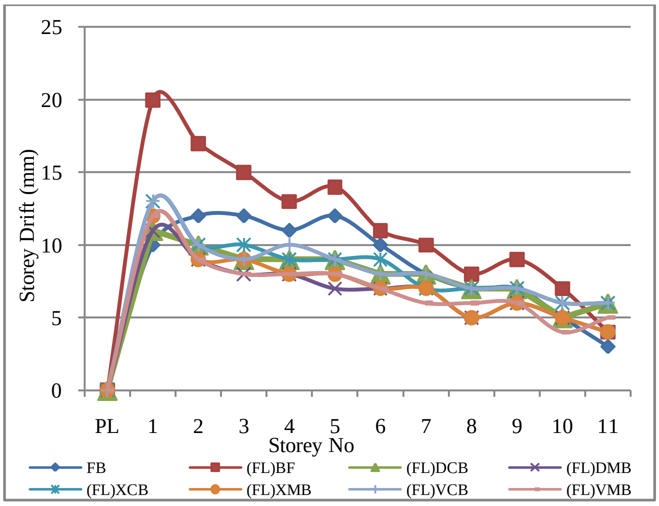


Fig -8: Variation of storey drift (G+10).

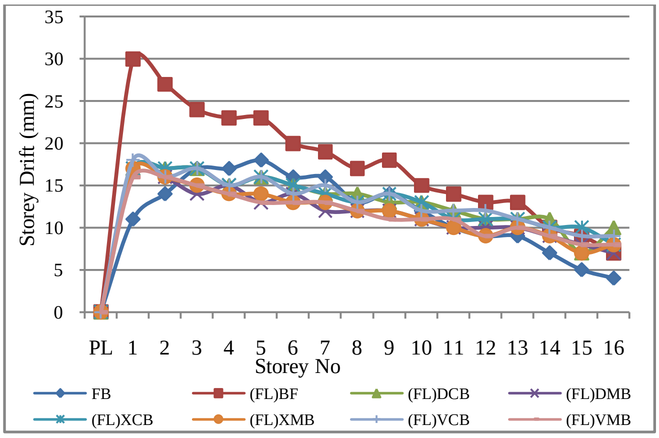


Fig -9: Variation of storey drift (G+15).

From Figure 8 it is observed that as the support flexibility changes from fix base to flexible base condition storey drift increases in the range of 40% to 100% for G+10 building. After the incorporation of various bracing system it reduces in the range of 30% to 45%. Among all position and orientation of bracings, the buildings with diagonal mid bracing that is FDMB has the least storey displacement. The same trend is observed for G+15 building.

5. CONCLUSION

1) Soil Structure Interaction (SSI) increases time period due to incorporation of flexibility at the base. It is also observed that increase in storey height increases the time period. Enlarged time period will lead to P-Δ effect and causes the excessive forces/ moments in the members which get magnified further with the increase in the flexibility of soil. Therefore SSI shall be considered in the analysis of structures especially when resting on relatively soft soil.

2) The provision of bracing is effective in high rise structure for controlling and reducing the damage during Earthquake. The study reveals that majority of parameters are reduced due to provision of diagonal mid bracing therefore it is more effective than the remaining combinations. Thus it is recommended to provide the bracing at mid location to minimize the SSI effect. The above conclusion is valid for symmetric building; however for unsymmetrical building there is need to carry separate analysis.

3) Provisions of bracing in the structure controls the SSI and in addition minimizes lateral displacement and storey drift, which will help to improve the performance of structure under seismic load.

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